

Aviation Weather Information Requirements Study

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Relation to Aviation Safety Program

- **Aviation Safety Program**

- Level 2 Element: Weather Accident Prevention (WxAP)
- Level 3 Project: Aviation Weather Information (AWIN)
 - **Paul Stough (LaRC)**
- Level 4 Sub-Projects: Enhanced Weather Products (ExWP)
 - **Phil Schaffner (LaRC)**

- Task: Aviation Weather Information Requirements Study
 - Georgia Tech Research Institute

AWIN Requirements Study Elements

- **Weather Data Product Investigation**
 - currently available data products and sources
 - important deficiencies
- **Aviation Weather Information Requirements Recommendations**
 - recommend AWIN requirements (content, coverage, timeliness) for all types of operators based on phase of flight
 - **requirements shall support both strategic and tactical decisions**
 - derive requirements for new or improved weather products
- **Investigation of Sensor System Uses, Needs, and Requirements**
 - compile information on fielded or developmental sensor systems
 - define candidate sensors (modifications or new) for missing weather products
 - airborne sensors, multi-sensor fusion, and EPIREPS to receive special attention
 - recommend new, improved, or modified sensor systems

Existing Weather Products

- **Design of current aviation weather products includes:**
 - specific atmospheric conditions
 - specific hazards
 - current and forecast conditions
 - **en-route**
 - **terminal area**
 - in-flight advisories
 - pre-flight planning

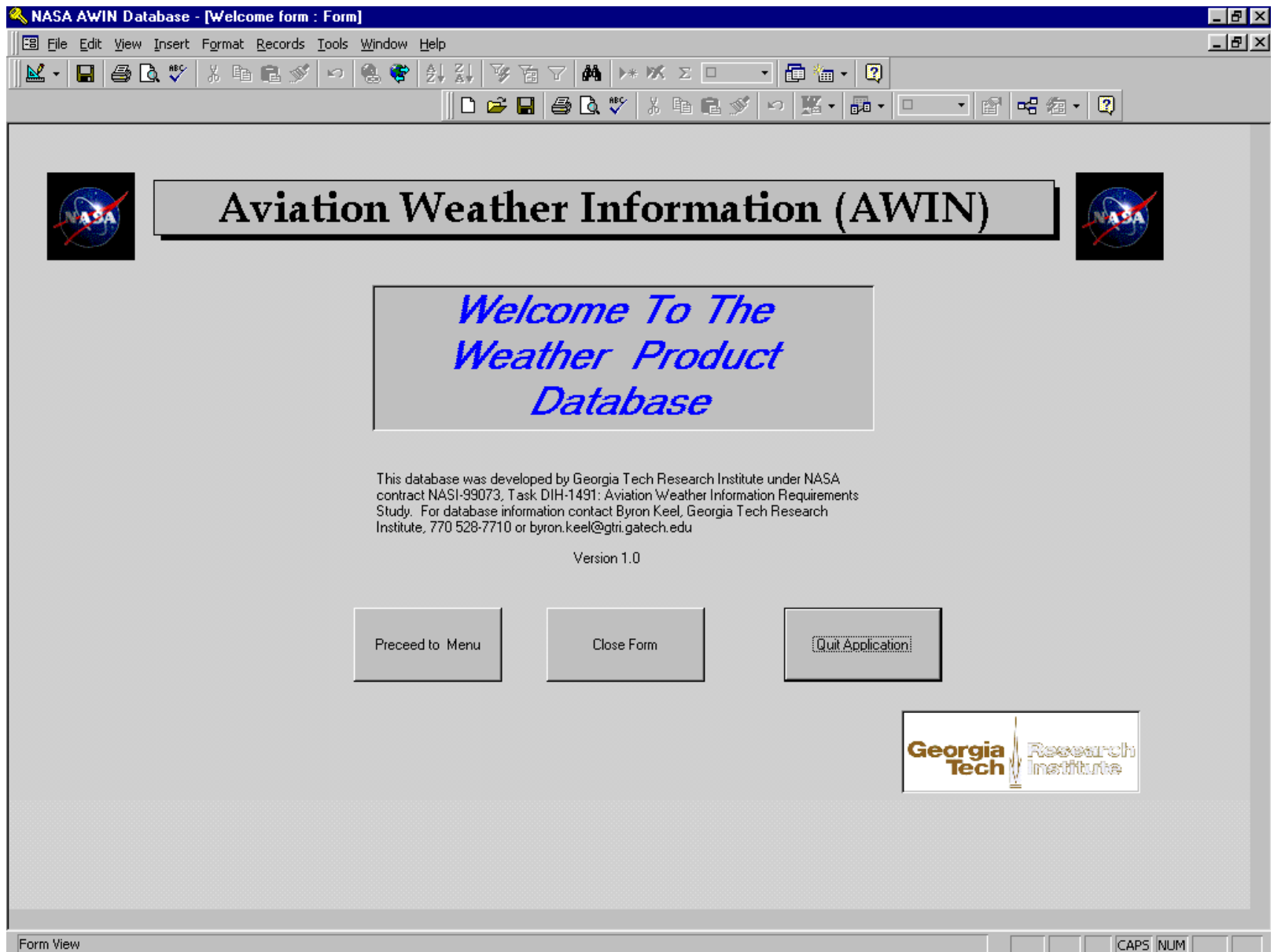
Sub-task 1: Weather Product Investigation

Weather Product Users Survey

- Within the confines of this task, GTRI identified key users of weather products representing a broad sampling of the user community.
- A weather product usage survey was developed and sent to the identified users.
- Visits were also made to a number of users:
 - United Parcel Service (UPS)
 - Delta Airlines
 - Southern Region Air Traffic Control
 - FAA - Flight Information Systems (FIS) Program
 - National Weather Service
- The visits and surveys were intended to provide an user/operational view of the current weather products.
- A statistical analysis was not possible within the confines of this task.

Weather Product Database

- **Relational weather product database developed using Microsoft Access.**
 - easy access to weather product information
 - access to survey information
 - tool for assessing deficiencies
 - **e.g., queries using a weather element, weather product, duration, frequency**
- **Weather product information included**
 - weather information source, route from origin to user, method of application, related economics, extent of use, latency, adequacy, criticality, information format, displays, availability, and required HW and SW.
- **Information sources included**
 - internet and literature searches
 - interviews
 - surveys



NASA AWIN Database - [Distinct_wxproduct_name]

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WEATHER PRODUCT SUMMARY

Name	Full Name	Description
AIRMET Sierra	Airman's Meteorological Information	Advises to single engine, light a/c and VFR pilots
AIRMET Tango	Airman's Meteorological Information	Advises to single engine, light a/c and VFR pilots
AIRMET Zulu	Airman's Meteorological Information	Advises to single engine, light a/c and VFR pilots
ALDARS	Automated Lightening Detection and Reporting Syst.	Eliminates manual obsv of lightening at airports
ASOS	Automated Surface Observation System	Primary surface wx observing system in the US
AVOSS	Aircraft Vortex Spacing System	Allow ATC's to reduce spacing in instrument ops
AWOS	Automated Weather Observation System	Provide local wx data directly to pilots
AWW / WW	Severe Wx Forecast Alerts/Severe Wx Watch	Define areas of severe thunderstorms or tornadoes
CWA	Center Weather Advisories	Unschd, inflt flow cont, air traf, air crew advis

Record: 1 of 45

Form View

Close Form

Limited Survey Participants

Part 135 Operators

Tri-Star

Epps Aviation (Charter)

Part 121 Operators

UPS

Delta Airlines

Northern Air Cargo (Alaska)

Part 91 Operator

Southern Company

Survey Identified Weather Product Deficiencies

- **Data format**
 - text versus graphics
 - assimilation
 - interpretation
- **Support System**
 - information dissemination
 - equity in information quality
 - aviation tailored weather information (spatial and temporal scales)

Deficiencies (continued)

- **Sensors**
 - Availability
 - RVR
 - TDWR
 - Regional
 - Confidence
 - LLWAS
 - Loss of Capability
 - Volcanic Ash
- **Sensors (cont'd)**
 - Lack of Capability
 - Turbulence
 - In-flight Icing
 - Hail
 - Ceiling and Visibility
 - Required Tuning
 - NEXRAD
- **Forecast and Modeling**
 - Convective Weather
 - Mesoscale Modeling
 - **Sensor grid**
 - **Fidelity**

Sub Task 2: Requirements & Recommendations

Approach Taken

- **Develop an understanding of weather phenomena and its impact on aviation**
- **Characterization of weather phenomena**
- **An analysis of the twelve phases of flight in terms of weather information content, coverage, and timeliness**
- **An analysis of the existing weather products**
- **A review of NTSB accident data where weather was a factor**
- **A review of recent (early 1990's) studies related to weather information requirements**

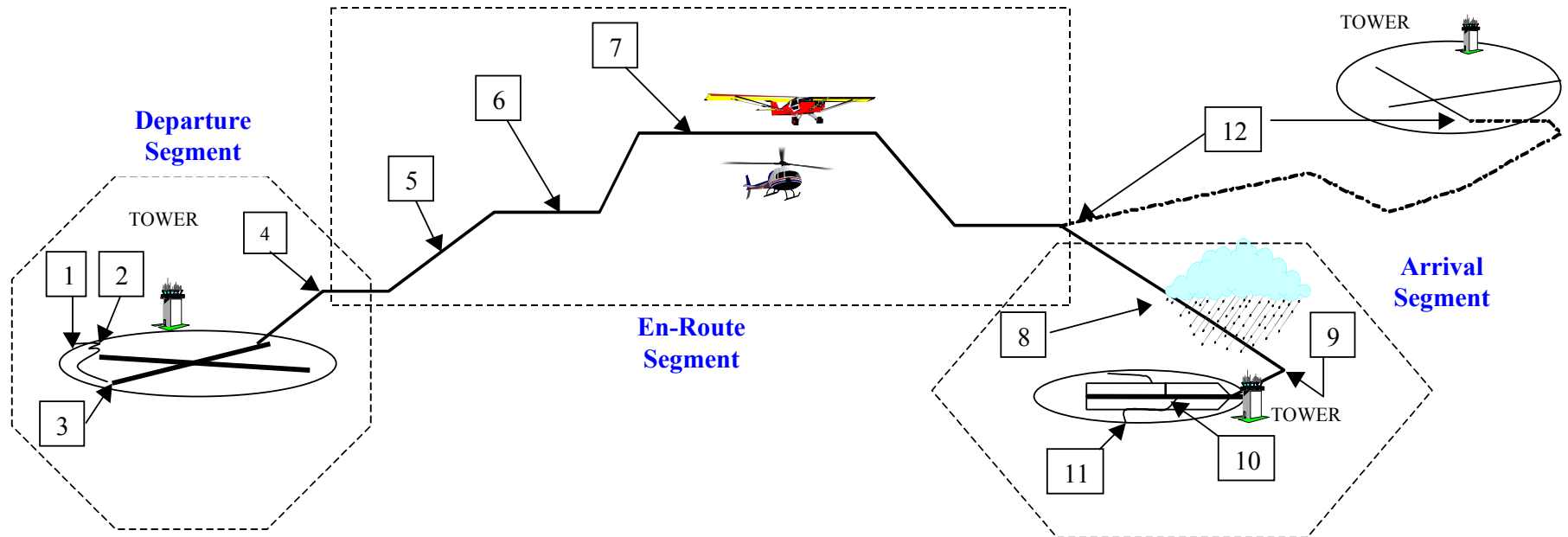
Recent Studies

- **Crabill, N. L., and E. R. Dash, “Pilot’s Weather Information Requirements and Implications for Weather Data Systems Design”, DTFA-01-90-01019, NAS1-18585, available via NTIS, April, 1991.**
- **“Two-Way Data Link versus Broadcast Communications for Flight Information Services”, RTCA SC - 169, Working Group 3, Cockpit Requirements Issues Subgroup, DRAFT, August, 1993.**
- **“Air Traffic Weather Requirements Report”, prepared by the Air Traffic Weather Requirements Team (ATWRT), February, 1993.**

Developing Phase of Flight Requirements

- **Assumption: all the FAR categories need similar information for safe flight.**
- **Regulatory issues were not addressed.**
- **Economic issues were not addressed.**
- **Requirements**
 - what weather information is needed
 - timeliness (forecast or current)
 - phase of flight

Phases and Segments of Flight



Phases of Flight

1. Preflight Planning; Flight Plan Filing	7. Cruise Operations
2. Preflight Operations	8. Approach Operations
3. Taxi Out and Take Off Operations	9. Landing Operations
4. Departure Operations	10. Taxi In and Parking Operations
5. Initial Climb Segment Operations	11. Post Flight Operations
6. Initial Cruise Operations	12. Alternate Operations (if required)

Information Requirements (example)

	Cruise						Approach						Landing					
	D		E		A		D		E		A		D		E		A	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
Weather Systems			X	X	X	X					X	X						X
Air Motion																		
Flight Level			X	X														
Terminal					X	X					X	X						X
Precipitation			X	X	X	X					X	X						X
Icing																		
Flight Level			X	X														
Terminal					X	X					X	X						X
Visibility																		
Flight Level			X	X														
Terminal					X	X					X	X						X
Lightning			X	X	X	X					X	X						X
Volcanic Ash			X	X	X	X					X	X						X
Wake Vortices																		X
Alternate																		
Route					X	X												
Terminal					X	X												

Code Key

D Departure Segment

E En-Route Segment

A Arrival Segment

F Forecasted Conditions

C Current Conditions

Requirement Recommendations

- **General Requirements**
 - Weather products to
 - **address the eight categories of weather phenomena.**
 - **address hazards in terms of forecasted conditions, current conditions (observations/measurements), intensity, location, extent, movement, and life cycle.**
 - **provide both strategic and tactical information as a function of phase of flight (previous tables)**
 - More accurate, localized descriptions of forecasted and current conditions tailored to the needs of the aviation community.

Requirement Recommendations

- **Terminal Area**

- Integration/fusion of weather sensors to develop an improved composite view of weather conditions in the terminal area
- Support three-dimensional wind sensing in the terminal area
- Support detection of wind phenomena that contain low levels of precipitants (e.g., dry microburst and gust fronts)
- Lower cost systems to support wind sensing in the terminal area (intended to increase the number of airports with this capability)
- Wake vortex detection and tracking in the terminal area under all weather conditions

Requirement Recommendations

- **Terminal Area (continued)**
 - A sensor system to provide real-time slant range visibility conditions along the glide slope
 - A system to sense and report runway surface conditions that relate to the pilot's ability to stop or maintain control of the aircraft while on the runway
 - A reduction in the number of airports where the pilot is required to rely solely on personal observation or PIREPS to obtain local information

Requirement Recommendations

- **In support of IMC & VMC**
 - Improvements in ceiling and visibility forecast
 - A real-time system providing current information on VMC and IMC on a finer time and spatial scale than currently exists

Requirement Recommendations

- **Pilot & Aircraft**

- An automated system allowing users to enter route and aircraft specific information that would then provide the pilot with tailored weather products to aid in pre-flight planning
- An increase in the update rate associated with weather products applied in pre-flight planning
- An automated system, requiring little pilot intervention, to deliver updates to the cockpit as weather conditions change
- A standardized three dimensional coordinate system (e.g., GPS coordinates) in which to describe a hazard's position, extent, and movement

Requirement Recommendations

- **Pilot & Aircraft (continued)**
 - On-board equipment to interpret position and movement of hazardous conditions (based on a standardized coordinate system) in relation to the aircraft's current position and intended route
 - An autonomous, on-board, expert system providing weather information in the cockpit in a graphical format
 - **capable of handling and interpreting large amounts of data**
 - **should provide specific options for the pilot**
 - Lower cost, on-board weather systems to support the smaller aircraft that fall under Part 91 operations
 - On-board sensors to provide inputs for EPIREPS

Requirement Recommendations

- **Specific Hazards**
 - On-board sensors to address
 - in-flight icing
 - turbulence
 - A replacement sensor for the GOES split channel to detect volcanic ash
- **Supporting Modeling**
 - Finer time and spatial separations between radiosonde measurements

Sub Task 3: Sensors

Weather Sensors in Support of Aviation

- **Aviation Weather Sensors**
 - FAA assets
 - NOAA/NWS assets
- **Application**
 - tactical
 - strategic
 - as input to forecast models (e.g. RUC model)
 - outputs used to derive other weather products
- **Sensor Types**
 - In Situ
 - Remote
 - Radar
 - EO/IR
 - Radiometers

Potential Sensor Solutions

Hazard/Phenomena	Potential Sensor
Hail	Polarization Diverse Radars
Icing	Temperature – Radiometry Water & Water Vapor – Dual Frequency Radar and Radiometry
Clear Air Turbulence	Lidar
Slant Range Visibility	Lidar
Vector Wind Sensing (terminal area) and Wind Shear Detection	Bistatic Doppler Radar Unisys Microburst Prediction Radar (an example)

Hail Detection

- Polarization is required for discrimination
- Research in this area has increased significantly over the past 5 - 10 years
- NSSL is planning to retrofit their WSR-88D with a polarization capability in FY01
- The CHILL radar is equipped with a dual polarization capability
- Research indicates that this is an area where enhancements could be achieved
- Polarization adds additional cost to the system

Terminal Area Vector Wind Sensing

- **Vector wind field sensing**
 - Bistatic approach
 - Transmitter: existing TDWR or ASR-9
 - Receiver: low cost bistatic receivers
- **Lower cost wind shear detection systems**
 - enhance LLWAS-NE or provide non-existent capability
 - a lower cost terminal area weather radar

PIREPS: Current System

- **ARTCCs and FSSs enter reports into the National Weather Service's Communication Gateway**
- **Reporting limited to selected frequencies**
- **Workload at FSS during critical time delays input of PIREPs**
- **Application**
 - warning other pilots
 - weather research
 - forecasting

Recommended Sensor Suite

EPIREP Reporting Options
Outside Temperature Sensor
Wind Speed and Direction Sensors
Relative Humidity Sensors
Location (GPS coordinates) and Time Stamp
Degree of Turbulence (accelerometers)
Weather Avoidance Radar Summaries
Icing Sensors on the Surface of the Aircraft

Comments

- **Sensor operating range and accuracy requirements are a function of the application: pilot information, research, forecasting**
- **The infrastructure is needed to process and interpret the EPIREP data once it becomes available.**
- **Additional sensors (e.g., lidar and radiometers) could be added to a limited number of aircraft in support of research efforts**
- **Providing growth for additional bandwidth is recommended for future sensor additions**

Summary

- **Results**

- Identified areas within the aviation weather product system that need improvement
- Developed a database containing current weather product information
- Developed weather product requirements in support of improved safety
- Identified potential sensor systems to help fill-in some of the gaps
- Identified suites of sensors for inclusion in EPIREPs
- Generated a contractor report: “Aviation Weather Information Requirements Study”, April 2000.

- **AWIN Follow-on Efforts**

- development of the design for a low cost terminal area weather radar
- a study and design of potential airborne radiometric sensors to aid in detection and avoidance of icing, turbulence, and volcanic ash

Appendix

Information Requirements

	Planning						Preflight Ops						Taxi and Take-off					
	D		E		A		D		E		A		D		E		A	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
Weather Systems	x	x	x	x	x	x	x	x										
Air Motion																		
Flight Level	x	x	x	x	x	x												
Terminal	x	x	x	x	x	x	x	x						x				
Precipitation	x	x	x	x	x	x	x	x						x				
Icing																		
Flight Level	x	x	x	x	x	x												
Terminal	x	x	x	x	x	x	x	x						x				
Visibility																		
Flight Level	x	x	x	x	x	x												
Terminal	x	x	x	x	x	x	x	x						x				
Lightning	x	x	x	x	x	x	x	x										
Volcanic Ash	x	x	x	x	x	x	x	x						x				
Wake Vortices														x				
Alternate																		
Route	x	x	x	x	x	x												
Terminal	x	x	x	x	x	x												

Flight Plan Considerations

VFR/IFR	Ground Speeds
Departure Time	Trip Time
Take-off and Climb Performance	Fuel Burn
Route	Arrival Time at Destination
Altitudes	Daylight/Darkness
Airspeeds	Alternate Conditions

Code Key

D Departure Segment

E En-Route Segment

A Arrival Segment

F Forecasted Conditions

C Current Conditions

Information Requirements

	Departure						Initial Climb						Initial Cruise					
	D		E		A		D		E		A		D		E		A	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
Weather Systems		X	X	X					X	X					X	X		
Air Motion																		
Flight Level			X	X					X	X					X	X		
Terminal		X																
Precipitation		X	X	X					X	X					X	X		
Icing																		
Flight Level			X	X					X	X					X	X		
Terminal		X																
Visibility																		
Flight Level			X	X					X	X					X	X		
Terminal		X																
Lightning		X	X	X					X	X					X	X		
Volcanic Ash		X	X	X					X	X					X	X		
Wake Vortices																		
Alternate																		
Route																		
Terminal																		

Code Key

- D** Departure Segment
- E** En-Route Segment
- A** Arrival Segment
- F** Forecasted Conditions
- C** Current Conditions

Information Requirements

	Taxi In						Post Flight Ops					
	D		E		A		D		E		A	
	F	C	F	C	F	C	F	C	F	C	F	C
Weather Systems						X					X	
Air Motion												
Flight Level												
Terminal						X					X	
Precipitation						X					X	
Icing												
Flight Level												
Terminal											X	
Visibility												
Flight Level												
Terminal						X						
Lightning												
Volcanic Ash												
Wake Vortices												
Alternate												
Route												
Terminal												

Code Key

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Back Up Material

Terminal / Route / Area Specific Conditions

Aviation Routine Weather Report (METAR)	<p>Content: Terminal area conditions: wind, visibility, runway visual range (RVR), weather phenomena, sky condition, temperature, dewpoint, altimeter</p> <p>Issued by: FAA, NWS, or contract personnel at the airport or by an automated system (e.g., AWOS or ASOS)</p> <p>Update: 1 hour</p> <p>Area: Terminal</p> <p>Type: Current Conditions</p>
Terminal Aerodrome Forecast (TAF)	<p>Content: Wind, visibility, weather, sky condition, and wind shear (non-convective)</p> <p>Issued by: NWS WFO</p> <p>Update: 6 hours (or as conditions warrant)</p> <p>Area: Within 5 miles of terminal area</p> <p>Type: Forecast</p> <p>Requires: Two consecutive METARs are required for the TAF to be issued.</p>
Route Forecast	<p>Content: Sustained surface winds, visibility, weather, thunderstorms, volcanic ash, sky conditions, mountain obscurements, non-convective low-level windshear</p> <p>Issued by: NWS WFO</p> <p>Update: 8 hours</p> <p>Area: 25 miles on either side of some 300 routes</p> <p>Type: Forecast</p> <p>Requires: A TAF must be issued for the airport for a route forecast to be issued.</p>
Aviation Area Forecast (FA)	<p>Content: Visual meteorological conditions, clouds, and general weather</p> <p>Issued by: Aviation Weather Center</p> <p>Update: 8 hours (as conditions warrant)</p> <p>Area: area the size of several states</p> <p>Type: Forecast</p>

In-Flight Weather Advisories

In-Flight Weather Advisories	
Convective SIGMET	<p>Issued for: Thunderstorms (TS): severe, embedded, and line of, heavy precipitation affecting 40% of 3,000 square mile area.</p> <p>Issued by: Aviation Weather Center</p> <p>Update: Hourly (or as conditions warrant)</p> <p>Reference: VORs, airports, or well known geographic areas</p>
Domestic SIGMET	<p>Issued for: Non-convective phenomena: severe icing, extreme or severe turbulence or CAT, dust and sand storms, volcanic ash</p> <p>Issued by: Aviation Weather Center</p> <p>Update: As conditions warrant</p> <p>Reference: VORs, airports, or well known geographic areas; generally widespread forecast</p>
International SIGMET	<p>Issued for: Thunderstorms, tropical cyclones, severe icing, severe or extreme turbulence, dust and sand storms, volcanic ash</p> <p>Issued by: ICAO Meteorological Watch Offices</p> <p>Update: As conditions warrant</p>
AIRMET Sierra	<p>Issued for: IFR weather conditions (< 1,000 ft. and 3 miles) affecting a large area, extensive mountain obscuration</p> <p>Issued by: Aviation Weather Center</p> <p>Update: 6 hours (as conditions warrant)</p>
AIRMET Tango	<p>Issued for: Moderate turbulence, 30 knot surface winds, low-level wind shear</p> <p>Issued by: Aviation Weather Center</p> <p>Update: 6 hours (or as conditions warrant)</p>
AIRMET Zulu	<p>Issued for: Moderate icing, freezing-level heights</p> <p>Issued by: Aviation Weather Center</p> <p>Update: 6 hours (or as conditions warrant)</p>
Meteorological Impact Statement (MIS)	<p>Issued for: Convective SIGMET criteria, icing, turbulence, surface winds, wind shear, volcanic ash, sand and dust storms</p> <p>Issued by: Center Weather Service Unit at ARTCC</p> <p>Update: As conditions warrant- event to begin beyond 2 hours</p>
Center Weather Advisory (CWA)	<p>Issued for: Weather phenomena that will impact air traffic flow within the next 2 hours.</p> <p>Issued by: Center Weather Service Unit at ARTCC</p> <p>Update: As conditions warrant; event to begin in less than 2 hours</p>
Severe Weather Watch Bulletin	<p>Issued for: A watch issued for areas where expected severe thunderstorms or tornadoes may exist.</p> <p>Issued by: Storms Prediction Center in Norman, Oklahoma</p> <p>Update: As conditions warrant</p>

Support Pre-Flight Planning & Strategic Decisions

Winds and Temperature Aloft Forecast	Content: Winds and Temperature Update: 12 hours Elevations: 3,000, 6,000, 9,000, 12,000, 18,000, 24,000, 30,000, 39,000, 45,000, and 53,000 ft (pressure alternate)
Radiosonde Additional Data	Content: Freezing level and relative humidity Update: 12 hours
Constant Pressure Analysis Charts	Content: Temperature, wind, dew point Update: 12 hours Elevations: 1,500, 3,000, 18,000, 30,000, 34,000, and 39,000 ft (pressure altitude)
Composite Moisture Stability Chart	Content: Stability, freezing levels, precipitation water, and relative humidity Update: 12 hours Elevations: Surface, 1,000, 850, 700, and 500 b/hPa
U.S. Low-level Significant Weather Prognosis	Content: Fronts, pressure centers, precipitation, TS, IFR, MVFR, turbulence, freezing levels Update: 6 hours Elevations: surface to 24,000 feet
High Level Significant Weather Prognosis	Content: TS, turbulence, fronts, jet stream, tropopause, volcanic activity Update: 6 hours Elevations: 25,000 to 60,000 ft (pressure altitude)
Convective Outlook	Content: Forecast of areas at risk for severe thunderstorms over the next 24-48 hours Update: 5 times per day
Surface Analysis Charts	Content: Pressure systems, isobars, and observable weather at reporting stations Update: 3 hours Elevation: Surface
Weather Depiction Chart	Content: Summary of METAR reports Update: 3 hours
Radar Weather Report	Content: Precipitation information Update: 1 hour
Radar Summary Chart	Content: Precipitation information Update: 1 hour
Satellite Weather Pictures	Content: Clouds: type and height Update: 0.25 to 1 hour
Hurricane Advisory	Issued for: Hurricanes 300 nm offshore Issued by: Tropical Prediction Center (Miami) Update: As conditions warrant
Volcanic Ash Forecast and Dispersion Chart	Issued for: Ash concentration forecast at different altitudes Issued by: NOAA Air Resources Laboratory (ARL) Update: 6, 12, 24, and 36 hours after a volcanic eruption

Additional Weather Products

Terminal Area Ground Based Sensor Systems

Microburst and Gust Front Detection

Low Level Wind Shear Alert Systems (LLWAS)

Terminal Doppler Weather Radar (TDWR)

ASR-9 with Weather System Processor (WSP)

Automated Surface and Terminal Area Observations

Automated Weather Observation System (AWOS)

Automated Surface Observation System (ASOS)

Runway Visual Range

Combined Systems

Integrated Terminal Weather System (ITWS)

On-board Weather Sensors

Pitot Tube

Storm Scope

Airborne Weather Radar

Pilot

Personal Observation

Pilot Reports (PIREPS)

FAA Weather Information Support Structure

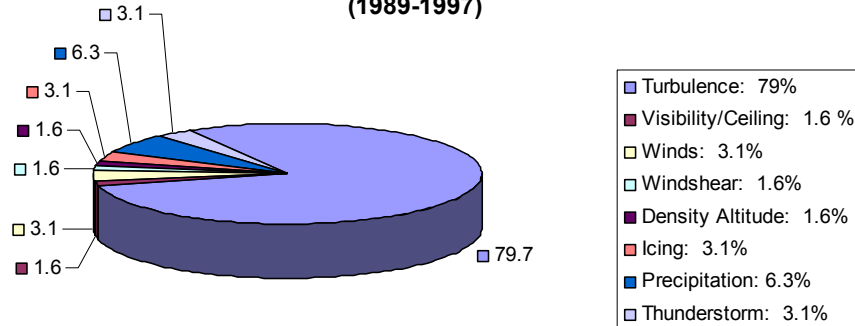
- **FAA National Air Traffic Control System's Central Office**
 - Herndon, Virginia
 - employs weather unit specialist
- **Air Route Traffic Control Centers (ARTCC)**
 - IFR air space management within 150 nautical mile jurisdiction
 - air route surveillance radar (ARSR)
 - center weather service unit (CWSU)
 - **NWS meteorologist**
 - **FAA support personnel**
- **FAA (Automated) Flight Service Stations**
 - Flight Watch
 - PIREPS
- **Airport Traffic Control Tower (ATCT) and TRACON**
- **Commercial Operation Centers**
 - Enhanced Weather Information Systems

Components of NOAA Supporting Aviation Weather Information

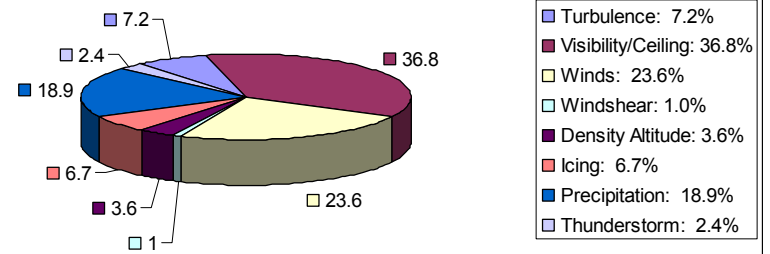
- **National Oceanic and Atmospheric Administration**
 - National Weather Service
 - **Nine National Centers**
 - National Center Operations (Washington, DC)
 - Aviation Weather Center (Kansas City, MO)
 - Storm Prediction Center (Norman, OK)
 - Tropical Prediction Center (Miami, FL)
 - **Weather Forecast Offices**
 - National Environmental Satellite, Data, and Information Service (NESDIS)
 - Oceanic and Atmospheric Research
 - **Environmental Research Laboratory**
 - National Severe Storms Laboratory
 - NEXRAD algorithm development
 - Forecast Systems Lab
 - wind profiler network

NTSB Supporting Data

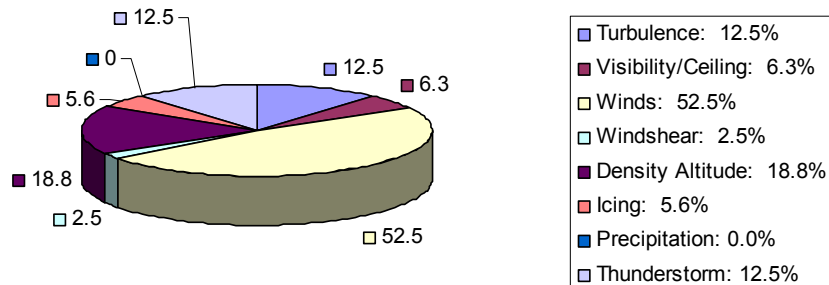
Part 121: Weather Related Accident Causes or Factors (1989-1997)



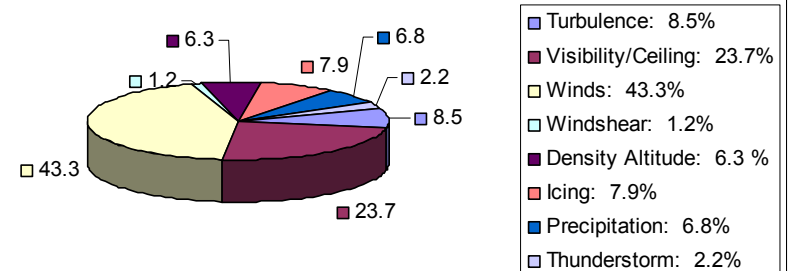
Part 135: Weather Related Accident Causes or Factors (1989-1997)



Part 137: Weather Related Accident Factors and Causes (1989-1997)



Part 91: Weather Related Accident Causes or Factors (1989 - 1997)



Categorizing Atmospheric Conditions

Weather Systems
Thunderstorms
Single Cells
Super Cells
Squall Lines
Mesocyclones
Tornadoes
Hurricanes
Pressure Systems
Warm and Cold Fronts

Precipitation
Rain
Snow
Hail
Sleet
Virga

Air Motion	
Terminal Area	Flight Level
Microburst (wet and dry)	Clear Air Turbulence
Gust Fronts	Mountain Waves
Low Level Wind Shear (non-convective)	Convective Turbulence
Sustained Surface Winds	Strong Updrafts
Gusts	Strong Downdrafts
Low Level Turbulence (convective)	Jet Stream
Low Level Jets/Nocturnal Jets	Frontal Shear
Land and Sea Breeze	Winds Aloft
Cross winds	
Topographically Induced Winds	

Icing	
Terminal Area	Flight Level
Temperature	Super Cooled Liquids
Precipitation	Temperature / Freezing Level

Categorizing Atmospheric Conditions (continued)

Visibility/Ceilings	
Terminal Area	Flight Level
Low Level Clouds	Cloud Ceilings
Fog	Cloud Cover
Rain	Rain
Snow	Snow
Dust/Sand Storms	
Smoke/Pollution	
Runway Visual Range Conditions	

Additional Categories
Lightning
Volcanic Ash
Wake Vortices

Radars

Radar	Frequency Band	Application
Airborne Weather Avoidance Radars	X or C	Airborne radars used for the detection of severe weather en-route and the detection of windshear on approach and take-off
TDWR	C	Ground based radars used to characterize weather conditions in the terminal area (e.g., microburst, gust fronts, storms tracks)
ASR-9 w/ WSP	S	Ground based airport surveillance radars retrofitted with a weather processor to duplicate the functionality of a TDWR
WSR-88D	S	The National Weather Service's ground based radar which serves a number of different organizations including aviation
ARSR	L	The ground based air route surveillance radar which offers limited precipitation rate information
Wind Profiler Network	UHF	A network of ground based wind profilers providing horizontal wind speed and direction as a function of altitude
RASS	UHF / VHF	A system composed of a wind profiler radar and an acoustic sounder used to measure temperature
Boundary Layer Profiler Network	UHF	A loose network of low cost, low power wind profilers used to measure wind profiles within the boundary layer.

Radars

Operational Radar Systems	Governing Agency	Operational Area	Number of Sites
Airborne Weather Avoidance Radars	Pilot/FAA Approved	On-board Aircraft	
Terminal Doppler Weather Radar	FAA	Terminal Area	45
Airport Surveillance Radar – 9	FAA	Terminal Area	34
Air Route Surveillance Radar	FAA	En-route	
Weather Service Radar – 88D	NOAA/NWS	Continental US	158
NOAA Wind Profiler Network	NOAA/NWS	Localized	34
Radar-Acoustic Sounding System	NOAA/NWS	Localized	8
Boundary Layer Profiler Network	NOAA/NWS	Localized	65

Developmental Radars

Experimental or Developmental Radar Systems
Terminal Area Surveillance System
Unisys Microburst Prediction Radar
SPY-1 Radar with a Weather Processor
Bistatic Multiple-Doppler Networks
Dual Doppler Radars
Dual Frequency Radars
Polarization Diverse Radars

EO/IR and Passive Millimeter Wave Sensors

Sensors
Radiometers
Electro-optic Sensors (visible range)
Infrared Sensors
Runway Visual Range Sensors
Ceilometers
Coherent Lidar

In-Situ Sensors

In Situ Sensor Systems
Automated Surface Observation System/ Automated Weather Observing System
Low Level Wind Shear Alert System
Meteorological Data Collection and Reporting System
Radiosonde

Additional Sensors

Sensor Systems
National Lightning Detection Network
Airborne Lightning Detection Sensors
Global Positioning System - Integrated Precipitable Water Measurement System
Integrated Terminal Weather Support System